# Development of the EDAMS using Algometer and Bio-potential Measurement

**G. R. Jeon, S. S. Kim, W. Y. Jang, G. C. Park, J. H. Kim, Y. J. Kim**

***Abstract*—A system for measuring the electrodermal activity (EDA) signal occurring at the region of the sweet glands in human body was implemented in this study. The EDA signal was measured at the region of sweet glands using the bio-potential measurement system (BPMS) while the pressure stimulation was being applied to the scapular region that the trigger point (TP) of the myofascial pain syndrome (MPS) patients occurs, using an algometer. The EDA measurement system (EDAMS) consisted of an algometer, the BPMS, and PC. The functions of three components of the EDAMS are as follows. The pressure stimulus was applied to the scapula region using an algometer after attaching Ag/AgCl electrode to the palm or finger. The EDA signal was measured using the BPMS, and then transmitted to PC for analysis. Two experiments were performed to evaluate the function and the clinical applicability of the EDAMS. First, experiment was performed for the evaluation of the linearity of the output pressure and the output voltage according to the pressure stimulus being applied by an algometer. To apply the pressure stimulus, the mass was put from 0.2 kg to 3 kg on the top of an algometer, indicating 0.23 to 3.44 kgf/cm$^2$ in pressure scale. The experimental results revealed that the linearity of the output pressure and the output voltage according to the mass (weight) applied to an algometer was 0.999 and 0.998, respectively. Second, the amplitude and the latency of the EDA signal acquired from electrode attached to the palm or the finger were analyzed when the pressure stimulus of an algometer being applied to the scapula region was increase. The latency of EDA signal decreased whereas the amplitude of EDA signal increased. The experimental results revealed that the amplitude of EDA signal measured at the palm was observed to be higher than that measured at the fingers. In addition, the latency of EDA signal measured at palm was observed to be 0.8 s shorter than that measured at the fingers. within the intensity of pressure stimulus applied by an algometer.**

***Index Terms*— Myofascial Pain Syndrome (MPS), Electrodermal Activity (EDA), Algometer, Trigger point, Sweet glands.**

## I. INTRODUCTION

An electrodermal activity (EDA) means the elecrodermal phenomenon occurring actively or passively in the skin and t he accessory organs. The secretion of sweet glands due to the reaction of somatosensory nervous system and sympathetic nervous system (SNS) increases in case of the mental tension , an excitement, and several external stimuli. EDA is a biome dical signal for measuring the impedance change in the skin caused by increased secretion of sweat glands. The EDA sign al is associated with the sweat secretion occurring in approxi mately 300 million eccrine sweat glands, and it is mainly gen erated at the skin surface that sweat glands are distributed, su ch as palms and soles. On the other hand, the distribution den sity of sweat glands is low at arms, legs, trunk, and etc. So fa r, the generating mechanism of the EDA signal has not been clearly clarified yet. When a variety of tension stimuli is appl ied to the sympathetic nervous system (SNS) in human body, the change of impedance occurs in the skin because the EDA signal is due to the influence of the SNS [1].

Studies on the mechanism of generating the EDA signal, characteristics of the EDA signals due to mental or physical stimuli, characteristics of the EDA signal for several sensible organs in the human body, and the analysis of the EDA signal caused by various diseases were performed by several researchers [3, 4]. Neumann et al. [5] announced that the EDA signal appearing in the skin was due to the activity of SNS by mental stimulation. Fowles et al. [6] performed that the EDA signal occured in the skin due to the response of SNS by physical stimuli. Freixa et al. [7] stated that the EDA signal was the electrical response occurring in the skin by the activity of ANS for the physical or mental stimulus, and also that the change of electric potential and conductivity occurred simultaneously. Hugdahl et al. [8] revealed that the EDA signals from the left and right side of the body were not identical. However, characteristics of the EDA signal according to the stimulus region of the right and left side of the body have not been reported up to now. Lacroix et al. [9] performed on the lateralization of EDA signal by the action of the cerebral hemisphere. The comparison of EDA signal difference between left and right region according to the stimulation led to the conclusion that the unilateral occured according to the method of stimulation. Jung et al. [10] stated the EDA signal occurred in sweat gland regions in case of applying the physiological stimulation, but the unilateral EDA signal occurred in case of applying the local somatosensory stimulation. Hellerud et al. [11] performed the study on the somatosensory using the EDA signal, Lim et al. [12] on the hearing sense, Bruggemann et al [13] on the vision sense, and Brand et al [14] on the olfactory sense. Although many studies have been performed for the EDA signal, the mechanism of EDA signal has not been fully elucidated to date. It has been only estimated that the EDA signal takes place through the activity of the skin and sweat glands via SNS.

The electrodermal activity measurement system (EDAMS) was implemented in this study for measuring the EDA signal occurring at the finger and the palm while applying the pressure stimulus to the scapula region using an algometer. The EDAMS was composed of the bio-potential measurement system (BPMS, P-400, PhysioLab, KOREA)

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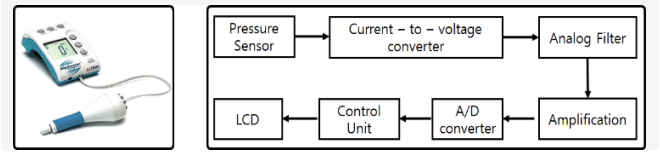
and an algometer (MM249_A, J. Tech. Co., USA), and PC. Two experiments were conducted using the EDAMS. First, the linearity of the output pressure and the output voltage of an algometer according to a mass (weight) was evaluated while putting a mass (0.2 kg) up to 3 kg on the top of an algometer. Second, the EDA signal was measured at the fingers and the palms while the output pressure or the output voltage of an algometer was being increased from 0 to 3.44 $\mathrm{kgf}/cm^2$ ( $3.77 \times 10^5\ Pascal$) in 0.23 $\mathrm{kgf}/cm^2$ ( $0.23 \times 10^5\ Pascal$) steps or from 0.1 to 0.8 V, after putting an algometer on the scapula region in human body, and then the amplitude and the latency of the measured EDA signal were analyzed.

## II. METHOD

### A. *Improvement of the function of an algometer*

In order to accurately detect the trigger point (TP) of the MPS patients, the tenderness threshold was detected using an algometer (MM249_A, J. Tech. Co., USA). In this study, an algometer being currently utilized in the pain clinic was used to detect TPs of the MPS patients. Appearance and block diagram of an algometer are shown in Fig.1.

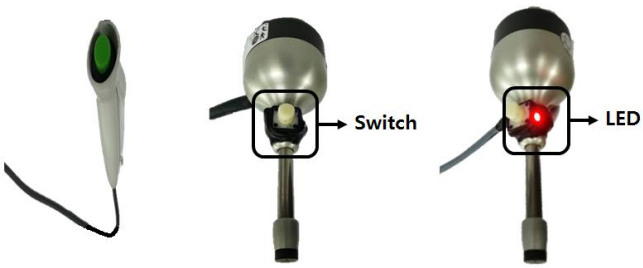



(a) (b)

Figure 1. Appearance and block diagram of an algometer: (a) appearance of algometer, (b) block diagram of algometer.

Conventional method and consequent problems for detecting TPs of the MPS patients using an algometer (MM249) are as follows. The pressure was gradually increased after putting an algometer on the scapula region of the MPS patients. When the patient reaches the point to feel the pain during increasing the pressure applied from an algometer, the patient appeals the pain by screams or beck as a painful sign, and an examiner stops the pressure applied to an algometer immediately. Then, an examiner confirmed the tenderness threshold by reading the applied pressure. However, an examiner cannot accurately measure the tenderness threshold of the MPS patient because an examiner is unable to stop an algometer at the moment that a patient appeals the pain, and rather, he/she stops an algometer after patient's appealing the pain. In addition, the tenderness threshold is differently measured according to the measurement region and the number of measurements. Also, the tenderness threshold depends on subjective sensation of the MPS patients. To solve these problems, button-typed switch and LED were mounted on an algometer so that a patient or an examiner can stop the pressure being applied from an algometer.

Fig. 2(a) is the external switch for the patient's pressing to stop the pressure being applied from an algometer when the patient feels the pain due to the pressure stimulus. Fig. 2(b) is the internal switch for examiner's pressing to stop the pressure being applied from an algometer while the patient expresses or appeals the pain due to the pressure stimulus. Fig. 2 (c) is LED to be lit when a patient or an examiner presses the switch for stopping the pressure stimulus.




(a) (b) (c)

Figure 2. The switch and LED fabricated for stopping and confirming the pressure being applied: (a) switch for a patient, (b) switch for an examiner, and (c) LED capable of checking the operation of the switch to stop the pressure being applied from an algometer.

Fig. 3 shows the circuit of an algometer modified for stopping and confirming the pressure being applied to perform the function described previously. In Fig. 3, 1 and 4 in switch part are switches for a patient to stop the pressure being applied, 2 and 3 in switch part are switches for an examiner to stop the pressure being applied, D1 is LED indicating a stop of the pressure being applied, and switch_out is the control signal for stopping the operation of a pressure sensor in an algometer.

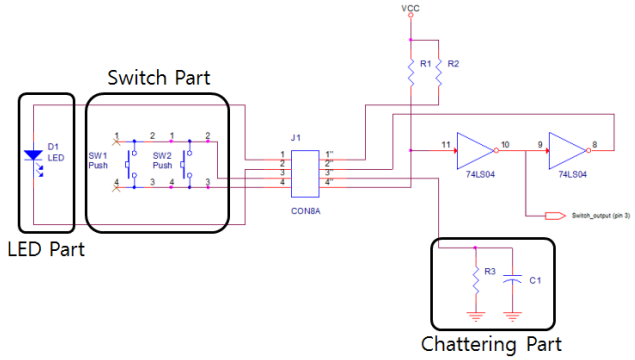



Figure 3. Designed circuit of switch and LED for stopping and confirming the pressure being applied.

### B. *Implementation of the EDAMS using an algometer and the BPMS*

In order to accurately and objectively detect TPs of the MPS patient, the EDAMS was implemented using an algometer and the bio-potential measurement system (BPMS, P400, PhysioLab, Korea). The EDA signal occurring in sweat glands due to the pressure stimulus being applied by an algometer was measured using the BPMS. Then, the EDAMS capable of detecting the position of TPs at the tenderness threshold by analyzing of the EDA signal was implemented.

Fig. 4 shows a block diagram of the EDAMS consisting of an algometer and the BPMS. The function of an algometer was previously described in section 2.1, and the function of the BPMS is as follows. First, the signal of pressure and voltage, which are the output signals of amplifier part in an algometer, was received in the BPMS1, and then the output signal of the BPMS 1 was transferred to PC via the amplifier rate selection, after adjusting an automatic null via a notch filter (60 Hz), a high-pass filter (HPF, 0.1 Hz), and a low-pass

filter (LPF, 20 Hz). Next, in the BPMS 2, after acquiring the EDA signal from Ag/AgCl electrode attached to the fingers and palm, a high-pass filter (0.1 Hz) for removing the baseline was used, an amplifier for amplification of 1,000 was used, and a low-pass filter (20 Hz) was used for removing for the power source noise and the mixed noise in measured EDA signal. In addition, the EDA signal was transferred to PC after sampling to 1,000 Hz using analog to digital converter (ADC) and quantizing to 8 bit. In PC, the signals of pressure and voltage transmitted from an algometer and the BPMS 2 were displayed on the monitor.

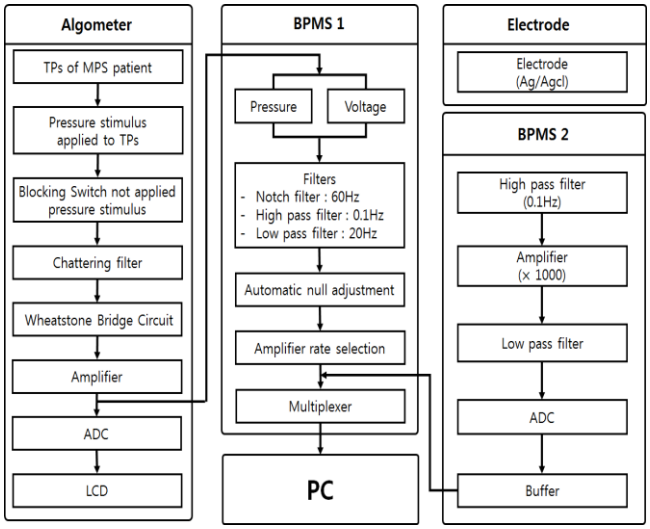



Figure 4. Block diagram of the EDAMS using an algometer and the BPMS.

## III. Subject and Experimental Protocol

### A. Subject

In order to perform this study, ten adults working in sitting long hours were selected as an experimental group. Experimental subjects were ten male adults with a mean age of 27.5 (±2.5 years), average height of 173 cm (±3.2 cm), and average mass of 75 kg (±4.1 kg). Experimental subjects are appealing the pain in the scapula region due to postural imbalance, and maintaining a fixed posture for long hours. However, they have no problems in the activity of the sweat glands.

### B. Experimental protocol

The experimental environment and the protocol are as follow. The room temperature in the laboratory was 23 ~25℃, and the relative humidity was maintained within the range of 60 ~ 70%. Experimental subjects were prohibited from taking coffee and smoking within 1 hour before the experiment, and were to take rest comfortably in spine posture. Before starting the experiment, an examiner briefly explained the principle of experiment and the measurement method to experimental subjects. Subjects are relaxed without tension during the experiment. To measure the EDA signal, Ag/AgCl electrodes were attached to the fingers and the palm of a subject as shown in Fig. 5.

(a) (b) (c)

Figure 5. The position of electrode attached for measuring the EDA signal: (a) method of Venables and Christe, (b) finger (A-B), and (c) palm (C-D).

The experimental subjects were sit on the chair, and then, the applying pressure was gradually increased after putting a n algometer on the scapula region. The EDA signal was mea sured while an examiner was applying the output voltage of an algometer from 0 to 0.8 V (output pressure was about 0 to 3.25 kgf/$cm^2$). The EDA signal measured at the fingers and the palm, and the pressure threshold value were transferred t o PC and then analyzed. The intensity of the pressure stimul us was divided into 8 steps from 0 to 3.44 kgf/$cm^2$ (0 to 3.37 $\times 10^5$ pascal). After taking 1 minute break between steps of the pressure stimulus being applied, subsequent experiments were conducted while increasing the intensity of the pressure stimulus of the following step.

## IV. Result

### A. Output characteristic of an algometer according to the applied pressure stimulus

The experiment for evaluating output characteristics of an algometer was performed according to the mass being applied to an algometer. The mass being put on the top of an algometer was increased from 0.2 to 3 Kg in 0.2 kg intervals. The pressure and the voltage being output from an algometer were measured 10 times according to the mass (i.e., weight). The linearity of the pressure and the voltage according to the mass was analyzed using the extrapolation method. The linearity of the output pressure and the output voltage was 0.999 and 0.998, respectively. Experimental results are shown in Fig. 6 and Table 1.

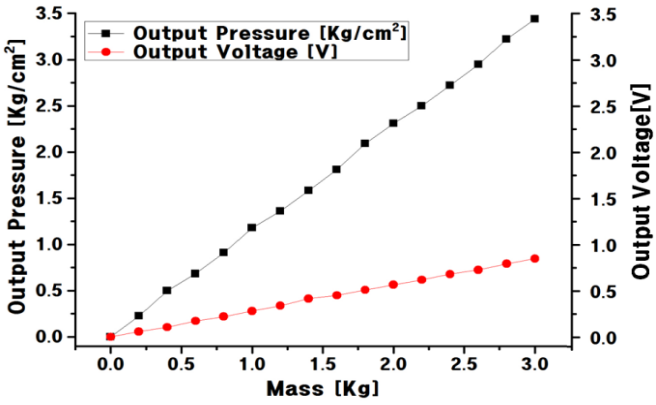



Figure 6. The output pressure and the output voltage according to the applied mass.

Table 1. The output pressure and the output voltage of an algometer according to the applied mass

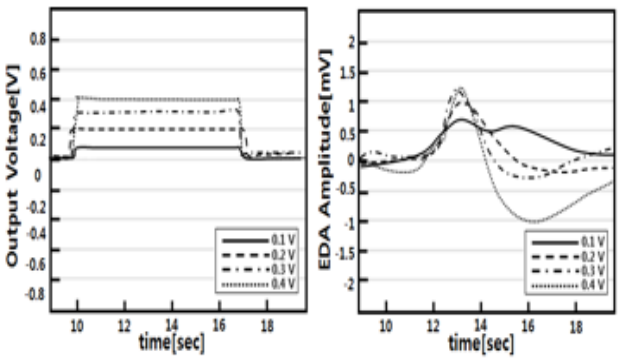
| Mass [Kg] | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 | 1.2 | 1.4 | 1.6 | 1.8 | 2.0 | 2.2 | 2.4 | 2.6 | 2.8 | 3.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $P_{AO}$ [kgf/cm$^2$] | 0 | 0.23 | 0.50 | 0.68 | 0.91 | 1.18 | 1.36 | 1.59 | 1.81 | 2.09 | 2.31 | 2.50 | 2.72 | 2.95 | 3.22 | 3.44 |
| or | | | | | | | | | | | | | | | | |
| Pascal [$10^5 P$] | 0 | 0.23 | 0.49 | 0.67 | 0.89 | 1.16 | 1.33 | 1.56 | 1.77 | 2.05 | 2.26 | 2.45 | 2.67 | 2.89 | 3.16 | 3.37 |
| $V_{AO}$ [$10^{-1}$ V] | 0 | 0.56 | 1.04 | 1.71 | 2.19 | 2.79 | 3.37 | 4.12 | 4.48 | 5.08 | 5.64 | 6.17 | 6.77 | 7.24 | 7.90 | 8.46 |
| $V_{SD}$ [$10^{-3}$ V] | 0 | 1.75 | 1.74 | 2.17 | 1.49 | 2.22 | 2.36 | 1.94 | 1.26 | 3.667 | 2.28 | 2.56 | 2.49 | 3.94 | 4.35 | 3.72 |

*B. Measurement of the EDA signal using an algometer and the BPMS*

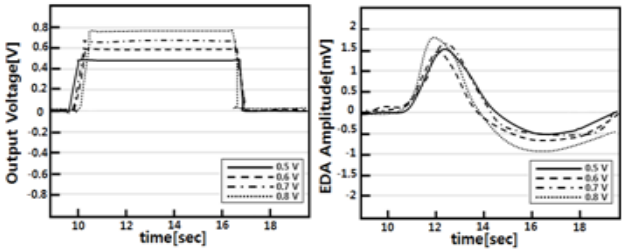
For measuring the EDA signal, electrodes were attached to the fingers and the palms of 10 experimental subjects as shown in Fig. 6. Then, an algometer was put on the scapular region for applying the pressure stimulus. While applying the output voltage of an algometer from 0.1 to 0.8 V, the EDA signal was measured using the BPMS. Experiments were also performed to analyze the difference of EDA signals depending on the attaching position of the electrode. Here, the pressure stimulus with the identical intensity by an algometer was applied to the scapular region for each pressure stimulus during 1 minute.

Fig. 7 shows the EDA signal measured at the fingers according to the output voltage of an algometer. Fig. 8 shows the EDA signal measured at the palm according to the output voltage of an algometer. The experimental result of Fig. 7 and Fig. 8 could be analyzed as follows. When the output voltage of an algometer applied to the scapula increased, the amplitude of EDA signal increased whereas the latency of EDA signal was shorter irregularly. For the intensity of the output voltage applied by an algometer, the amplitude of EDA signal measured at the fingers was lower than that measured at the palm. In addition, the latency of EDA signal measured at the fingers was longer than that measured at the palm.

The experimental results illustrated in Fig. 7 and 8 are represented in Table 2.

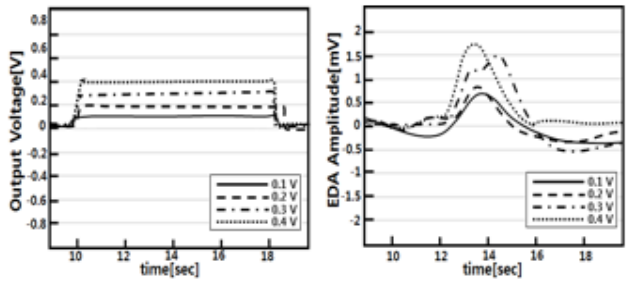



(a)

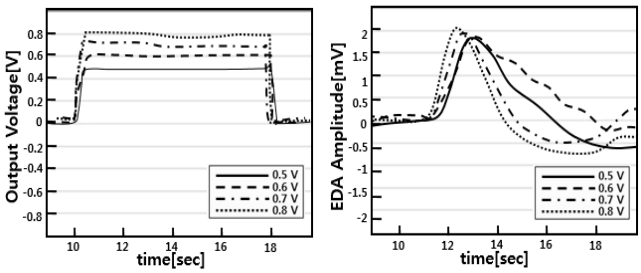



(b)

Figure 7. EDA signal measured at the fingers (A and B of Fig. 5) when the output voltage of an algometer from 0.1 to 0.8 V was applied to the scapula region: (a) EDA signal for the output voltage of an algometer from 0.1 to 0.4 V, (b) EDA signal for the output voltage of an algometer from 0.5 to 0.8 V.




(a)




(b)

Figure 8. EDA signal measured at the palm (C and D of Fig. 5) when the output voltage of an algometer from 0.1 to 0.8 V was applied to the scapula region: (a) EDA signal for the output voltage of an algometer from 0.1 to 0.4 V, (b) EDA signal for the output voltage of an algometer from 0.5 to 0.8 V.

**Table 2. Comparison of the latency and the amplitude of EDA signal measured at the palm and the fingers**

| Intensity of | Amplitude | | Latency | |
|---|---|---|---|---|
| output voltage [V] | Finger[mV] | Palm[mV] | Finger[s] | Palm[s] |
| 0.1 | 0.38 ± 0.08 | 0.62 ± 0.06 | 2.11 ± 0.18 | 0.62 ± 0.13 |
| 0.2 | 0.75 ± 0.06 | 0.85 ± 0.05 | 2.26 ± 0.16 | 1.43 ± 0.17 |
| 0.3 | 1.18 ± 0.11 | 1.33 ± 0.04 | 2.18 ± 0.12 | 0.68 ± 0.09 |
| 0.4 | 1.47 ± 0.05 | 1.72 ± 0.12 | 1.66 ± 0.08 | 0.92 ± 0.12 |
| 0.5 | 1.51 ± 0.07 | 1.78 ± 0.15 | 2.15 ± 0.11 | 1.46 ± 0.15 |
| 0.6 | 1.62 ± 0.17 | 1.89 ± 0.19 | 1.98 ± 0.09 | 1.83 ± 0.18 |
| 0.7 | 1.69 ± 0.16 | 1.92 ± 0.11 | 1.53 ± 0.14 | 1.47 ± 0.09 |
| 0.8 | 1.77 ± 0.11 | 2.01 ± 0.07 | 1.82 ± 0.19 | 0.92 ± 0.10 |

For the output voltage of an algometer applied to the scapular region, characteristic of the amplitude and the latency of EDA signal measured at the finger and the palm is as follows. First, when the output voltage of an algometer was increased from 0.1 to 0.8 [V], the amplitudes of EDA signal measured at the finger and the palm were increased from 0.38 to 1.77 mV and from 0.62 to 2.01 mV, respectively. In addition, the mean and standard deviation of the amplitude of the EDA signal measured at the fingers and the palm was 1.296 ± 0.101 mV and 1.515 ± 0.099 mV, respectively. The difference of the mean and standard deviation of the amplitude of EDA signal measured at the fingers and the palm was 0.219 ± 0.002 mV. And, the linearity of the amplitude of EDA signal measured at the fingers and the palm was 0.999 and 0.998, respectively.

Second, when the output voltage of an algometer was increased from 0.1 to 0.8 [V], the latency of EDA signal measured at the fingers and the palms were increased from 1.53 to 2.26 s and from 0.62 to 1.83 s, respectively. The mean and standard deviation of the latency of EDA signal measured at the finger was 1.961 ± 0.134 s whereas the mean and standard deviation of the latency of EDA signal measured at the palm was 1.166 ± 0.129 s. The difference of the mean and standard deviation of the latency between palm and finger was 0.795 ± 0.005 s. And, the latency of EDA signal measured at fingers and palm was irregular. Therefore, the linearity of the latency of EDA signal measured at finger and palm could not be calculated exactly.

These results can be explained as follows. When the pressure stimulus is applied to the scapula region, the changes in the amplitude of the measured EDA signal according to output voltage of an algometer occur, depending on the length of the somatosensory nerves. In other words, the amplitude of EDA signal measured at the finger was small compared to that at the palm, because the length of the somatosensory nerves from the scapula region to the finger is longer compared to that to the palm. However, when the output voltage of an algometer is applied to the scapula region, the pressure stimulus generate a reflection in reflex arc of the spinal cord while moving to the central nervous system through the somatosensory nerves, and returns to the fingers and the palm through the sensory nervous system. The signal by the spinal cord reflex reaches late at fingers because fingers are far from the scapula relative to the palm. .

In other words, the latency at the fingers was observed to be longer than that at the palm due to the path difference of the sensory nervous system between the region applying the pressure stimulus and the region measuring the EDA signal [15]. When the output signal of an algometer was increased from 0.1 to 0.8 V, the latency of EDA signals measured at the finger and the palm was increased from $1.53 \pm 0.14$ to $2.26 \pm 0.16$ s and from $0.62 \pm 0.13$ to $1.83 \pm 0.18$ s , respectively. With respect to the increase of the output voltage of an algometer, the latency did not decrease at a constant rate, but rather exhibited the irregular values.

The reason the linearity of latency is low compared to that of amplitude is due to the difference of functional structure of electroneurogram (ENG) causing the reflexly evoked field potential. In other words, that is due to the differences in the number of the discharging motor neurons and fluctuating background neural condition within the spinal cord. In addition, the nerve field potential can be evoked by applying the stimuli to the mixed nerves with motor nerves and sensory nerve components, and then, the resultant nerve field potentials are derived from two types of active fibers.

In addition, when a peripheral nerve is stimulated and an evoked field potential is recorded in the muscle, the second potential (H wave) occurring late than the initial response (M wave) can be recorded. The latency of initial response decreases as the stimulation is brought closer to the muscle. However, the second response may exhibit a progressively greater latency as the stimulus is brought closer to the muscle. For the latency of the second response, the activity can travel proximally along sensory nerves as far as the spinal cord to elicit a spinal reflex. Furthermore, the latency of the EDA signal is differently measured according to the intensity of pain according to the subject, the distribution of TPs, and the activity of the sympathetic nervous system.

## V. Conclusion

For measuring the EDA signal using an algometer and the BPMS, the EDAMS was implemented in this study. That is, EDAMS capable of measuring the EDA signal being generated in the region of sweat glands due to the pressure stimulus applied by an algometer was implemented using the BPMS and PC. EDAMS was composed of an algometer, BPMS, and PC monitor. To evaluate the performance and the clinical applicability of EDAMS implemented, two experiments were conducted as follows.

First, experiment was conducted on the evaluation of the linearity of an algometer used for applying the pressure stimulus. The linearity of the output voltage and the output pressure of an algometer was evaluated according to the mass to be applied to an algometer. While putting the mass of 0.2 kg on the top of an algometer up to 3 kg in 0.2 kg

intervals, the pressure and the voltage being output from an algometer were measured 10 times according to the mass of the weight. Thus, the linearity of the output pressure and the output voltage was analyzed according to the mass. From the linear regression analysis, the output voltage and the output pressure according to the mass were 0.999 and 0.998, respectively. Second, experiment was carried out to evaluate the clinical applicability of the implemented system. After connecting an algometer to the scapula regions for 10 subjects, the difference of the EDA signals was analyzed according to the position of the electrode attached to the fingers and palm while applying the output voltage of an algometer from 0.1 to 0.8 V. As the output voltage of an algometer applied to the scapula increased, the amplitude of the EDA signal being measured at the finger and the palm was increased. On the other hands, the amplitude of the EDA signal measured at the finger was observed to be lower than that measured at the palm. In addition, for the intensity of the output voltage of an algometer, the latency of the EDA signal measured at the fingers was observed to be longer than that measured at the palm. These phenomena are due to the path difference of the somatosensory nerve between the region for applying the pressure stimulus and the region measuring the EDA signal. For the intensity of the pressure stimulus applied by an algometer, the latency of the EDA signal is not linearly changed whereas the amplitude of the EDA was increased linearly.

## ACKNOWLEDGMENT

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